

Unsteady Three-Dimensional Simulation of a Shear Coaxial GO₂/GH₂ Rocket Injector with RANS and Hybrid-RAN-LES/DES Using Flamelet Models

Historically, the analysis and design of liquid rocket engines (LREs) has relied on full-scale testing and one-dimensional empirical tools. The testing is extremely expensive and the one-dimensional tools are not designed to capture the highly complex, and multi-dimensional features that are inherent to LREs. Recent advances in computational fluid dynamics (CFD) tools have made it possible to predict liquid rocket engine performance, stability, to assess the effect of complex flow features, and to evaluate injector-driven thermal environments, to mitigate the cost of testing. Extensive efforts to verify and validate these CFD tools have been conducted, to provide confidence for using them during the design cycle. Previous validation efforts have documented comparisons of predicted heat flux thermal environments with test data for a single element gaseous oxygen (GO₂) and gaseous hydrogen (GH₂) injector. The most notable validation effort was a comprehensive validation effort conducted by Tucker et al. [1], in which a number of different groups modeled a GO₂/GH₂ single element configuration by Pal et al [2]. The tools used for this validation comparison employed a range of algorithms, from both steady and unsteady Reynolds Averaged Navier-Stokes (U/RANS) calculations, large-eddy simulations (LES), detached eddy simulations (DES), and various combinations. A more recent effort by Thakur et al. [3] focused on using a state-of-the-art CFD simulation tool, Loci/STREAM, on a two-dimensional grid. Loci/STREAM was chosen because it has a unique, very efficient flamelet parameterization of combustion reactions that are too computationally expensive to simulate with conventional finite-rate chemistry calculations. The current effort focuses on further advancement of validation efforts, again using the Loci/STREAM tool with the flamelet parameterization, but this time with a three-dimensional grid. Comparisons to the Pal et al. heat flux data will be made for both RANS and Hybrid RANS-LES/Detached Eddy simulations (DES). Computation costs will be reported, along with comparison of accuracy and cost to much less expensive two-dimensional RANS simulations of the same geometry.

Note: Some AIAA Abstracts (including Ref. [3] here) do include references. The references are:

[1] P. K. Tucker, S. Menon, C. L. Merkle, J. C. Oefelein, and V. Yang. Validation of high-fidelity CFD simulations for rocket injector design. AIAA Paper 2008-5226, (2008).

[2] S. Pal, W. Marshall, R. Woodward, and R. Santoro. Wall heat flux measurements for a uni-element go₂/gh₂ shear coaxial injector, 2006. Third International Workshop on Rocket Combustion Modeling, Paris, France, March, 13-15 (2006).

[3] S.Thakur, J. Wright, M. Ihme, and P. K. Tucker. Simulation of a Shear Coaxial GO₂/GH₂ Rocket Injector with DES and LES Using Flamelet Models. AIAA Paper 2012-3744, (2012).